SYSTEMATICS AND THE CONSERVATION OF BIOLOGICAL DIVERSITY[1]

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ABSTRACT

This paper concerns the role of systematics in efforts to conserve biological diversity. Biodiversity is seen both as an interdisciplinary science (involving ecology and population biology as well as systematics), and as a socio-political activity (because of the strongly anthropocentric focus of the Convention on Biological Diversity). Systematics has a number of key roles to play, especially with respect to maximizing our limited and fragmentary knowledge of biology through the predictive power of natural classification, and in helping to set priorities for conservation when, as is inevitably the case, resources are limited. After examining ways in which systematists must support the growing needs of society to know more about the Earth's biota, it is concluded that, because of their unique insights into the subject, systematists have an equally strong responsibility to take an active lead in many of the issues relating to the study, use, and conservation of biological diversity.

Dan Janzen (1993) has asked "What does tropical society want from the taxonomist?" In relation to the urgent need to know more about biological diversity, this question raises further issues—notably, is biodiversity only really important in the tropics, and does taxonomy only have a supporting role in the study of biodiversity? Here I will discuss all three questions, taking the view that taxonomists, and systematists in general, need to be proactive as well as supportive in their work.

SHOULD SYSTEMATISTS TAKE A LEAD IN THE STUDY OF BIODIVERSITY?

The subtitle of *Global Biodiversity Strategy* (Reid et al., 1992), one of the key documents produced before the 1992 UNCED conference, is "Guidelines for action to save, study, and use Earth's biotic wealth sustainably and equitably." The earlier *Caring for the Earth* (IUCN/UNEP/WWF, 1991) has the subtitle "A strategy for sustainable living." The primary objectives of the Convention on Biological Diversity are "the conservation of biological diversity ... the sustainable use of its components ... and the fair and equitable sharing of the benefits arising from the use of genetic resources" (Glowka et al., 1994). Thus many of these goals are unashamedly anthropocentric and primarily concerned with conservation for human benefit, rather than preservation of wildlife for its own sake.

Whether or not this "rampant, unapologetic utilitarianism" (Porritt, 1994) is the best strategy is open to debate (e.g., Allen & Edwards, 1995; Oates, 1995), but this is where most of the force behind national and international conservation efforts is now located. The Global Environment Facility (Glowka et al., 1994), the interim financial mechanism of the Convention (currently administered by the World Bank), is the largest single source of funding ever made available for work on biodiversity—a funding source which systematists seem surprisingly slow to exploit. As Robert May (1990) has observed, "Without taxonomy to give shape to the bricks, and systematics to tell us how to put them together, the house of biological science is a meaningless jumble." If systematics provides the foundation of our understanding and ability to communicate about biological diversity, what role should systematists seek to play in the study, use, and conservation of the Earth's biotic wealth?

WHAT IS BIODIVERSITY?

An impression can readily be formed from much of the modern bioscience literature that the study of biological diversity is the preserve, not of systematics, but of ecology. The study of diversity rests neither with one nor the other, but with both. Biodiversity exists at the interface of pattern and process, as for example in the twin hierarchy envisaged by Eldredge and Salthe (1984; Table 1), in phylogenetics and population genetics (the distinc-

Table 1. The twin biological hierarchy (based on Eldredge & Salthe, 1984).

Genealogical hierarchy [pattern]	Ecological hierarchy [process]
Codons	Enzymes
Genes	Cells
Organisms [individuation]	Organisms [physiological function]
Demes	Populations
Species	Local ecosystems
Monophyletic taxa	Biotic regions
All life	Entire biosphere

tion between phylogenetic and tokogenetic relationships: Hennig, 1966), and in historical versus ecological biogeography (Myers & Giller, 1988).

Olivier Rieppel (1988) has discussed in depth a number of the scientific and philosophical issues of the pattern versus process debate. He observed that the analysis of pattern and process represents different and incompatible "ways of seeing," as "the first emphasises discontinuity, while the other is based on the principle of continuity." The two are complementary because pattern analysis offers the only guide to common ancestry, and so gives direction to the analysis of process, while process analysis is the only way of giving pattern a causal explanation. He finally concluded, given we have different ways of seeing biology, that we should accept that each has its merits and faults, and that each is incomplete by itself. Being complementary, we should make use of both approaches to get as complete a picture of biology as possible (Rieppel, 1988, esp. 170–171). Because of this intimate interrelationship, it is essential that systematists work together with ecologists and population biologists to develop a fuller understanding of biological diversity, including its potential uses—and, most urgently, to develop more effective strategies for its conservation.

SYSTEMATICS AND THE USE OF BIODIVERSITY

Current estimates of the number of extant species of organisms vary from 3 to 100 million; Hammond (1992) gave a carefully considered estimate of 12.5 million, but confidence limits on such figures are incalculable. There is greater agreement about the number of species that have been formally described (in the region of 1.5–1.8 million) but, even so, the uncertainties of synonymy ensure that the limits remain difficult to assess (Solow et al., 1995). The complications of heterozygosity, variation in genome size and degree of similarity/dissimilarity between species, and basic uncertainties about how to delimit the number of genes even in well-known organisms, compound any attempt to estimate the protean diversity that occurs at the genetic level. Undeterred, Wilson (1992) has estimated something in the order of 10^{17} nucleotide pairs as specifying the diversity among species, together with more than 10^{18} gene combinations potentially available per typical species. Taxonomists might seem like chemists with a knowledge of 10 elements from the Periodic Table, while geneticists might be compared to physicists trying to understand the Universe from the behavior of just a single fundamental particle. Is our ignorance of the biosphere really so extreme?

In 1973 a mealybug was discovered attacking cassava in Africa. By the end of 1989 this pest was causing massive crop losses throughout the African tropics. Initial attempts to find a natural biocontrol agent failed, until it was realized that the mealybug was part of an undescribed species complex, and that it only occurred naturally in the southern Neotropics (Cox & Williams, 1981). An appropriate encyrtid wasp was then found, tested, and introduced into Africa. The wasp has now spread over more than 12 million km^2 and gives effective control of the mealybug throughout its African range, with an annual cost benefit estimated at $200,000,000 (Herren & Neuenschwander, 1991).

This example, involving a new pest and an equally unknown biocontrol agent, tells us something special about the nature of our ignorance. Biology has to deal with a staggering number of specifics—there are thousands of mealybugs, and tens of thousands of encyrtid wasps. To solve the problem, entomologists had to find out precisely *which* mealybug they were dealing with, locate this species in its natural habitat, and discover precisely which of all those wasps was *one that attacked it.* The only reason this could be done quickly is because the existing classification of bugs and wasps, however incomplete, is sufficient to form a valid basis for *prediction.* Once the mealybug had been accurately located in the system, it was possible to predict its geographical origin, and then what sort of insect to look out for as a natural biocontrol agent. Our detailed knowledge of the biology of all these myriad species inevitably lags behind our knowledge of their classification, but the natural system allows us to extrapolate what knowledge we do have.

Thus our ignorance of biology, while profound, is manageable insofar as our classifications are predictive. Far from being a passive pigeon-holing activity as some seem to believe, classification has all

the properties of an intelligence system, often allowing us to go far beyond the seemingly limited information available. Although there are literally millions of undescribed species, nearly all animals and plants can readily be placed within meaningful families. Like hypotheses, good classifications "allow limited data to be used with remarkable effect, by allowing interpolations through data-gaps, and extrapolations to be made to new situations for which data are not available" (Gregory, 1980).

One of the most frequently proposed uses for biodiversity is biochemical prospecting. Costa Rica's INBio has even formed contractual agreements with international pharmaceutical companies. Gámez and Gauld (1993), in describing the Costa Rican experience, suggested that the Hymenoptera, with their multitude of species and pharmacologically active venoms and other secretions, are a potentially excellent source of valuable new chemicals. While this is undoubtedly true, the same can be said for almost any diverse group.

Schulz et al. (1993) examined the male pheromone-gland secretions of 10 African milkweed butterflies, separating 214 substances in 14 chemical classes. Individual species had from 12 to 59 compounds (excluding tetrahydrofurans, which were not systematically investigated), including a high proportion restricted to individual species, or just a few, usually closely related species. Among these were some compounds rarely or never found in nature before, such as the ketone 16-heptadecen-2-one from *Amauris hecate*, and the monoterpene (*E*)-2,6-dimethyl-5-octen-1,8-diol from *Danaus chrysippus*. If we wished to prospect for closely related substances in other species, the existing cladistic classification (Ackery & Vane-Wright, 1984) would give us immediate and obvious clues—such as the chemically uninvestigated *Amauris dannfelti* and *A. inferna* for the ketone, and *Danaus gilippus* for the terpene.

This suggests that, armed with an appropriate classification, chemical prospecting need not be "blind": if we find something interesting, we can look at closely related species with the heightened expectation of finding more of the same or related compounds. If, on the other hand, we want to select, say, the 10 most different species out of a sample of 1000, to maximize the chance of finding radically different chemicals per unit effort, we can make use of the diversity measurements developed in systematic conservation evaluation (see below). Either way, the natural classification offers the most intelligent basis for biochemical prospecting, or for any other use that depends on predicting the biological properties of organisms. The better our classifications are, the more explanatory power they will have (Farris, 1979, 1983), and the more effective they will be for making such predictions.

SYSTEMATICS AND CONSERVING BIODIVERSITY

There are two major strands to conservation biology: where to conserve living things, and how to conserve them (Caughley, 1994). The latter represents a major application of ecology and population biology. Regarding the former, systematists have been closely involved with recent developments (e.g., see Forey et al., 1994), including the formulation of new approaches to measuring diversity that take account of phylogenetic relationships.

According to Taylor (1978), the notion of diversity, as an interrelation of species richness and individual abundance, was first recognized by Henry Walter Bates. Bates's idea, to evaluate the diversity of a locality and compare it with that of another, was later formalized as α-diversity (Whittaker, 1965). Whittaker (1972), while elaborating a more complex scheme (α-, β- and δ-diversity) to take account of species turnover at varying spatial scales (Magurran, 1988, gave a review of the considerable variety of procedures that have now been proposed for the measurement of "ecological diversity"), also suggested that time, in addition to richness and spatial turnover, should be included in a more complete expression of diversity. Time is the primary dimension of evolution along which differences between lineages accumulate.

Conservation biologists, concerned with the need to set priorities for the preservation of genetic diversity, have recognized the same problem and proposed that this could be solved, to a first approximation, by mobilizing information contained within the taxonomic hierarchy: "The size of the potential genetic loss is related to the taxonomic hierarchy because, ideally at least, different positions in this hierarchy reflect greater or lesser degrees of genetic difference and hence differences in such variables as morphology, behaviour, physiology, chemistry and ecology. Although the degree of difference (the gap) between genera and between species within genera varies both within and among classes, the current taxonomic hierarchy provides the only convenient rule of thumb for determining the relative size of a potential loss of genetic material" (IUCN/UNEP/WWF, 1980).

Vane-Wright et al. (1991) proposed a diversity metric sensitive both to individual taxonomic (hierarchical, not formal) rank and total number of species found within an area. This index, subsequently called root-weight, was the first formal measurement of taxic diversity. In a series of pa-
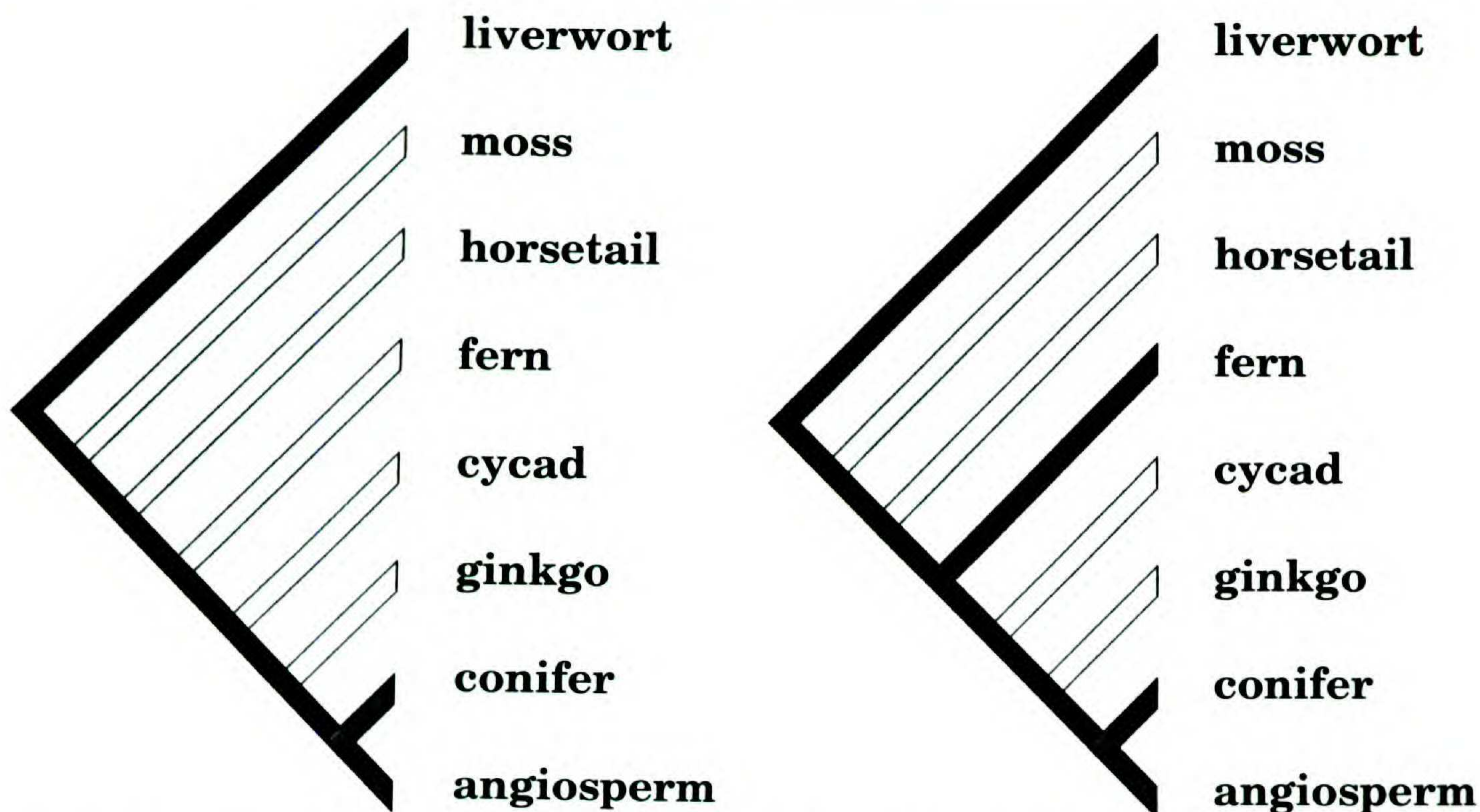
Figure 1. Choosing three land plants from eight: based on the cladogram, which combination would maximize biodiversity? Character richness (on the left) chooses liverwort, conifer or angiosperm, plus any one of the series moss–*Ginkgo*; character combination richness (right) selects liverwort, fern, and conifer or angiosperm. (Assuming all character changes are associated only with nodes shown and a comparable number of character changes occur at each node; based on Williams & Humphries, 1994; hierarchical relationships of plants from Humphries & Parenti, 1986.) See text for explanation.

pers, notably those of Williams (e.g., Williams, 1993; Williams et al., 1991, 1993, 1995; Humphries & Williams, 1994), Weitzman (1992), Nixon and Wheeler (1992), and Faith (e.g., 1992, 1994), the concept of taxic diversity has been refined and clarified—notably with respect to the fundamental question of what is being measured, and why.

Humphries et al. (1995) concluded that the current goal is to assess option value. This concept offers "a means of assigning a value to risk aversion in the face of uncertainty" (McNeely, 1988), and can be related to the task of "maximising the human capacity to adapt to changing ecological conditions" (Reid, 1994). If this is accepted, then we can abandon the insoluble problem of trying to assign fixed values to individual species (Ehrenfeld, 1988) and focus our attention instead at the level of expressible and heritable characters (genes, traits, features, etc.; Faith, 1992, 1994; Williams et al., 1995), which, collectively, can be considered to represent the fundamental currency units of option value.

Thus a set of species can be evaluated in terms of the total number of different characters they represent. The impact of losing (or the addition of) any particular species can be measured in the same way, thus fulfilling the need to assess "the size of

potential genetic loss" (or gain). In practice, however, it is impossible to measure character differences directly on a large enough scale, and so the distribution of characters across taxa has to be modeled. It is now agreed that this should be based on the genealogical hierarchy, as expressed more and more accurately by taxonomic ranks, cladograms, and phylogenetic trees. Debate continues, however, regarding which model of character change should be applied (e.g., empirical versus anagenetic versus cladogenetic), and whether or not differences should then be assessed in terms of character richness only, or character combination richness (Williams et al., 1995).

Some idea of the two approaches is given by Figure 1. Suppose we could only select for conservation three of the eight land plant species shown. If species richness were the only criterion, then any of the 56 combinations of 3 species from 8 would be equally acceptable. But if we interpret the tree subtending the eight species as a statement about their mutual phylogenetic relationships, then on the basis of just this information (making the assumption that a comparable number of character changes occur between each node shown), only 10 combinations will maximize character richness (liverwort plus conifer or angiosperm, plus any one from the

Table 2. Complementarity: the eight plants listed in Figure 1 have been allocated to five hypothetical areas; l = liverwort, m = moss, f = fern, y = cycad, g = ginkgo, n = conifer, a = angiosperm, h = horsetail. (Based on Underhill, 1994; see text for explanation.)

Species:	l	m	f	y	g	n	a	h
Area 1	−	−	+	+	+	+	+	−
2	+	+	+	+	−	−	−	−
3	−	−	−	−	+	+	+	+
4	+	+	+	−	−	−	−	−
5	−	−	−	−	−	+	+	+

series moss-*Ginkgo*). Alternatively, we could choose to maximize character combination richness, but then only two possible combinations are selected: liverwort, fern, plus conifer or angiosperm. (The root-weight index, if the cladogram is rooted between liverwort and moss, would restrict the choice to liverwort, moss, and horsetail—but this index is no longer regarded as appropriate.) Despite some significant differences in these results, when large numbers of taxa are involved, simple species richness for an area usually turns out to be a good approximation for both character richness and character combination richness (Williams & Humphries, 1994).

We now seem close to a satisfactory theoretical basis for at least part of what May (1990) has called the "calculus of biodiversity." Another, and perhaps even more significant aspect of the procedure, is provided by the concept of complementarity.

WHERE IS BIODIVERSITY MOST IMPORTANT?

COMPLEMENTARITY AND ITS IMPLICATIONS

In Table 2 the eight land plants in Figure 1 have been allocated to five areas. Suppose you were told that you could only choose one area for conservation, which would you select? Guided by species richness alone, area 1 would seem an obvious choice. What if you were then asked to add a second area? The greatest number of additional species to the five already represented by area 1 is two (liverwort and moss), both of which can be added by area 2 or area 4. Area 1 plus area 2 or 4 can thus account for seven of the eight species; the eighth (horsetail) could then be added by a third area (3 or 5). If, however, you were asked to select just sufficient areas from the outset to represent all eight species, it is obvious by inspection of Table 2 that areas 2 and 3 together include all of them, giving a more efficient final solution than adding areas step by step, starting with the richest first.

In reality both procedures have a place. Often it may not be possible to represent all species, vegetation types, or land forms from the outset, in which case a step-wise procedure may be the most appropriate. In other cases, it may be possible to select from the beginning a set of areas to represent all known (or vulnerable, etc.) biological attributes in a region, in which case a set-wise procedure will usually offer a more efficient analysis. (In this particular example, it is interesting to note that application of a taxic diversity index, such as character richness, identifies both areas 2 and 3 as richer than area 1, based on the hierarchy given in Figure 1, illustrating the point that species richness should not be regarded as the sole determinant of taxic diversity.)

Both the step-wise and set-wise procedures reflect the idea of complementarity: the degree to which specified areas, singly or in combination, represent the species or taxic diversity of an entire group or set of groups. Complementarity, first applied by Kirkpatrick (1983) and Ackery and Vane-Wright (1984), and formalized by Vane-Wright et al. (1991; see also Margules et al., 1988; Rebelo & Siegfried, 1992; Pressey et al., 1993; Faith, 1994; Williams & Humphries, 1994) has much in common with β- and δ-diversity but, crucially, instead of just reducing taxon turnover to numerical values or indices, information on the identity of taxa between areas is retained.

Although deceptively simple, the emergence of the idea of complementarity has been significant for biodiversity evaluation. This is because it has shifted attention from assessing areas on an absolute scale (e.g., richness or scoring index) to a relational scale (taking account of spatial turnover). In this way, all areas can be seen as part of a whole. For example, while tropical forests and coral reefs may be the richest biological systems on Earth, the very distinct biota of other ecosystems, such as those of ocean bottoms or the relatively species-poor higher latitudes, also have a unique contribution to make (Table 3). Complementarity provides a basic criterion for efficient and goal-directed procedures of area selection.

PRIORITIES IN CONTEXT

If we take into account quantitative effects of biodiversity (Cousins, 1994), particularly in relation, for example, to ecosystem services (Ehrlich & Daily, 1993), or the value of local biodiversity to humanity (Gadgil, 1991, 1992), it is evident that all areas of the Earth should be seen as important. Recognizing unique value for a particular area does

Table 3. Essentially extratropical plant familes (from Heywood et al., 1978). Most contain only one or a few species.

S. Hemisphere	N. Hemisphere	Bipolar
Lactoridaceae	Trochodendraceae	Lardizabalaceae
Gomortegaceae	Cercidiphyllaceae	Empetraceae
Malesherbiaceae	Eucommiaceae	Juncaginaceae
Achariaceae	Leitneriaceae	Posidoniaceae
Grubbiaceae	Paeoniaceae	
Cephalotaceae	Diapensiaceae	
Penaeaceae	Theligonaceae	
Misodendraceae	Hippuridaceae	
Geissolomataceae	Cynomoriaceae	
Calyceraceae	Cneoraceae	
	Limnanthaceae	
	Phrymaceae	
	Adoxaceae	
	Butomaceae	
	Scheuchzeriaceae	

not mean that adjacent areas are unimportant, or that they can be abused with impunity. Priorities should not be seen as merely choosing a few of the richest, or even most complementary sites, but more in differential allocation of resources (Vane-Wright, in press) to do the best we can, in relation to relative importance both in terms of pattern and process, across all areas of land and sea. Nevertheless, for the establishment of a network of special areas to act as reserves to ensure that as much of the irreplaceable qualitatively different (genealogical) elements of diversity survive, and are thus available to future generations, analyses based on complementarity among areas supporting vulnerable attributes (gene, species, assemblages) will be of great importance if the limited resources currently available for biodiversity conservation are to be used to maximum effect (Pressey et al., 1993; Pressey, 1994). The whole must be managed as effectively and sensitively as possible; within such a whole, a network of special reserve or management sites for biodiversity then has special significance and can serve a useful function.

WHAT SHOULD SYSTEMATISTS DO FOR SOCIETY?

REACTION

Commenting on his own question, "What does tropical society want from the taxonomist?", Dan Janzen (1993) observed that "The wording of the chapter heading is the message. I do not ask 'What does the taxonomist have to offer tropical society?' Tropical society's needs recently have been, can be and should be a major rejuvenating force in systematics." According to this view society and, in particular, tropical society, is looking to systema-

tists to make certain things possible. First and foremost, according to Janzen, a "cleaned up" set of names and a manageable system is needed for "filing, comparing, searching, recording and working with the species ... that constitute the ... bountiful biodiversity resource of tropical nations." Based on Janzen's ideas, and those of others like Stork (1994) and Nielsen and West (1994), I list below some areas in which systematists are being called upon to respond.

General attitude change. There is a need to demystify taxonomy and, in the process, make taxonomic products (such as identification systems and catalogues) more accessible (Miller, 1994). Much of this attitude change relates to gathering systematic data in the first place, and processing it in a way that not only offers self-satisfaction (peer group approval), but also satisfies the rapidly expanding needs of non-specialists.

Improved taxon sampling, recording, and storage. Better distributional data, including bionomic information such as host associations, etc., are essential (Wheeler, 1995; McNeely, 1995). Existing information is often based on ad hoc sampling procedures, resulting in a partial and disconnected coverage. Systematists should become involved with radical approaches to rational and cost-effective methods for data collection and spatial modeling, as well as application of techniques for improving estimates of distributional patterns based on existing data (Margules & Austin, 1991, 1994). This need includes dealing with the almost overwhelming number of (mainly species-level) taxa that remain unrecognized and undifferentiated (Wilson, 1992). Once biological samples have been

made, their continuing availability in well-documented and properly curated collections is fundamental to future work, including the extraction of information (such as DNA data) not necessarily considered at the time of original acquisition (Vane-Wright & Cranston, 1992).

Better systematic analysis. Because knowledge of the Earth's biota will inevitably remain incomplete, I have argued above that it is essential to place what knowledge we do have in as powerful a predictive system as possible (cf. Nielsen & West, 1994). This applies not only to the primary activity of classification, where phylogenetic methodology should be pursued vigorously in building a natural system, but also to secondary disciplines such as biogeography where, for example, the possibility of recognizing areas of endemism still offers much in terms of predictive power, or information (Platnick, 1991).

User-oriented databases. In order to make systematic, taxonomic, distributional, and bionomic data, together with information about the uses and values of different organisms, as widely available as possible, user-oriented electronic databases must be developed and made widely available by appropriate means (e.g., Internet: Miller, 1994; cf. Cracraft, 1995). In order to do this, it has to be understood that continuing problems will occur over costs and intellectual property rights, and these problems (including cost recovery and academic recognition) need to be solved.

Improved use of advanced technology. As part of the inevitable change to electronic methods for storing, analyzing and making systematic data more widely available, every opportunity should be taken to make increasingly imaginative use of computer and video technology. One of the most obvious areas lies in the development of fully illustrated, multiple-entry, interactive keys (currently based, for example, on CD-ROM technology: e.g., ETI, 1992; Watson & Dallwitz, 1993), but many other opportunities exist, such as the production of special checklists or other products tailored to fulfill unique needs, or the application of shape-analysis to identification. Other advances in biotechnology, leading to automated identification procedures based on blood or other tissue samples, or rapid increases in the quantity and quality of sequence data, must also be expected. The community of systematists should embrace these positive and exciting developments because, so long as they are properly set up, such information systems will give systematists more time to develop their basic and

traditional taxonomic skills—skills that will remain fundamental to further development and application of systematics to the problems of biodiversity.

Training new systematists. Under this heading we must acknowledge the need not only to be involved in training new generations of systematists, but also with institution building, such as the creation of new museums and reference collections. Assistance with the development of national biodiversity institutes (Gámez & Gauld, 1993) is likely to represent a particular challenge.

Involvement with biodiversity projects. The emergence of "biodiversity" as a topic (Harper & Hawksworth, 1994) raises many issues, not least of which is the fear that it may only represent a transient "band-wagon," likely to run out of steam or backfire on those who become too deeply committed. On the contrary, because the concept links concerns over the preservation of nature and its use directly to the needs of human society, it represents a fundamentally new way of thinking about biological diversity. Systematists need to play their part in the support of biodiversity projects, including such diverse activities as preparing user-friendly identification systems, training parataxonomists, being involved with surveys and inventory schemes, setting up museums, reference collections, and other information systems, making conservation and environmental evaluations, and so on. Biodiversity is a key social issue (Machlis, 1992), and it is vital that systematists play their part, not least by being sensitive to and catering for user needs (including local names, natural products information, etc.—things sometimes considered outside our remit).

Involvement with education. Because biodiversity is important and will remain so in the future, systematists should expect to play a full and active role in building public awareness (Cracraft, 1995), including, in particular, the education of young people (e.g., Yen, 1994).

PROACTION

The activities listed above are described in terms of responding to the needs of society for better, more comprehensive, and above all more accessible information about the Earth's biota and its significance. Appropriate reactions by systematists to the needs of society undoubtedly form part of our responsibilities (especially as society at large has already paid for so much of the collections, libraries, and other paraphernalia essential for our operations). However, as I will argue in the last section, it is also our responsibility to be proactive—to put

forward new ideas and create better attitudes to biodiversity by taking initiatives based on our own unique insights.

Take just one example. If we attempt to set conservation priorities based on separate analyses of the distributions of species belonging to more than one taxonomic group, it is apparent that this typically leads to different, sometimes totally different, conclusions about what actions are needed (e.g., Prendergast et al., 1993). Can such conflicts be resolved? Systematists have proposed two approaches to solving this problem: taxon summation (Vane-Wright et al., 1994), and the use of higher taxa (Williams et al., 1994). Although further work on both methods (which are not necessarily exclusive) is needed, the point here is that systematists tend to propose very different sorts of solutions than ecologists or population biologists.

Many ideas will need thorough evaluation before we settle on the most appropriate information and methods for priority areas analysis. Only by mobilizing systematic data, and creating the means to interpret it in a logical and systematic way, will we be able to develop efficient plans and monitoring schemes for conserving biodiversity. A primary goal is simply to make the most of limited resources that, inevitably, will never be enough to do everything that might be considered desirable. Systematics Agenda 2000 can lead here by promoting a network of systematists to create the wide range of species-level and higher-category databases which, together with appropriate analytical procedures, will be needed for a comprehensive approach to conservation evaluation.

OUR RESPONSIBILITIES AS SYSTEMATISTS

The burgeoning human population, driven by consumerism and poverty, is having a massively deleterious effect on biological diversity, through industrial pollution, resource appropriation, overcropping, and ecosystem transformation. We see local and global extinctions on the one hand, and the spread of a limited range of synanthropic species on the other, leading to extinction of taxa and even entire ecosystems, extirpation of myriad populations, and widespread loss of complementarity. Diversity is being diminished and homogenized.

As human demand for resources in both the developed and developing world continues to grow, so the rate of human-induced biodiversity loss accelerates. The end-point is unknown, as are the consequences. All we can say is that the biosphere, on which our life is totally dependent, will be called upon to provide more and more food, timber, and fiber, more clean water, more clean air, while absorbing more pollutants, all from a continually diminishing biotic base, quantitatively and qualitatively.

Faced with this alarming prospect, most nations have now agreed, at least in principle, to try to take some form of corrective action, to which almost universal support (at least on paper) for the Convention on Biological Diversity bears witness. This requires that each nation ratifying the Convention should pursue, through various provisions outlined, the conservation of biodiversity, the sustainable use of its components, and the fair and equitable sharing of benefits arising from the utilization of genetic resources.

As I have already suggested, this approach to biological diversity is radically different from previous concerns of the conservation movement, such as the protection of rare and endangered species, or the preservation of wilderness areas. The difference relates to the anthropocentric focus: human needs constitute both the threat and the solution. That is not to say that conservation will be compromised: on the contrary, conservation has shifted, in theory, from pressure-group status to being part of the fabric of human society. Conservation, and specifically the needs and uses of biodiversity, are now in the realm of what might be termed social engineering.

So biological diversity is, all of a sudden, big business. In relation to biological science in general, and to the community of professional conservationists, ecologists, systematists, and so on, this is good news. However, the arrival of biodiversity as a political issue does not just signal new sources of funds. We need to appreciate fully (unless we allow ourselves to be prey to the worst sort of cynicism), first that biodiversity is couched within a truly social framework (we are thus operating beyond the strict confines of science, in the areas of policy and socio-economics), and second, that we have new and expanded responsibilities that we, the community of systematists, must face up to. This includes the fact that much of the best data about biodiversity lies buried in our collections and libraries.

In my view, it is very much part of our responsibilities to take control and help shape policy through our own initiatives. We hold the best insight into the strengths and weaknesses of taxonomy and systematics. We, very largely, are paid out of public funds, and thus hold the responsibility not only to react supportively to the needs of society at large, but also to mobilize, make use of, communicate, and even lobby for the unique insights

that only we are in a position to formulate or bring to bear. Our responsibilities go beyond simply giving support when asked: we must also ensure that our knowledge and understanding are brought to the fore, to be judged useful—or not—as others decide.

Death and the Compass is the title of a short story by Jorge Luis Borges (1970). A criminal investigator has been set the task of trying to discover the murderer of a Jewish academic. At the scene of the crime, and in response to a suggestion that the scholar was accidentally murdered by somebody really intending to rob the man living next door, the investigator replies, "Possible but not interesting. You'll reply that reality hasn't the least obligation to be interesting. And I'll answer you that reality may avoid that obligation but that hypotheses may not. In the hypothesis that you propose, chance intervenes copiously. Here we have a dead rabbi; I would prefer a purely rabbinical explanation, not the imaginary mischances of an imaginary robber."

A multitude of taxa are under threat of death. In sympathy with Borges's investigator, we should not avoid the burden of providing an intellectually sound and satisfying solution. We need a systematic as well as an ecological chart of the biosphere (Eldredge & Salthe, 1984; Rieppel, 1988), and should develop a systematic plan to outwit as many imminent taxic deaths as possible. In short, we must endeavor to find what we believe to be an appropriate scientific solution, which takes full account of the principles and insights of systematics, in the same way that Borges's investigator sought an interesting explanation for the rabbi's fate.

But Borges's story carries not only this message for us, but also a dire warning. The investigator, besotted with pursuit of an intellectual game of death, ends up as the final, ultimate victim. While our work must be interesting, systematic, academically sound, it must also be timely, realistic, practical. We must be vigilant to ensure that Systematics Agenda 2000, or whatever we like to call our current game plan, is not merely self-seeking, not merely more of the same, time-worn, mutton dressed as lamb, old wine in new bottles, but really is oriented outward, toward society at large, to fulfill our responsibilities as true guardians of biological diversity.

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